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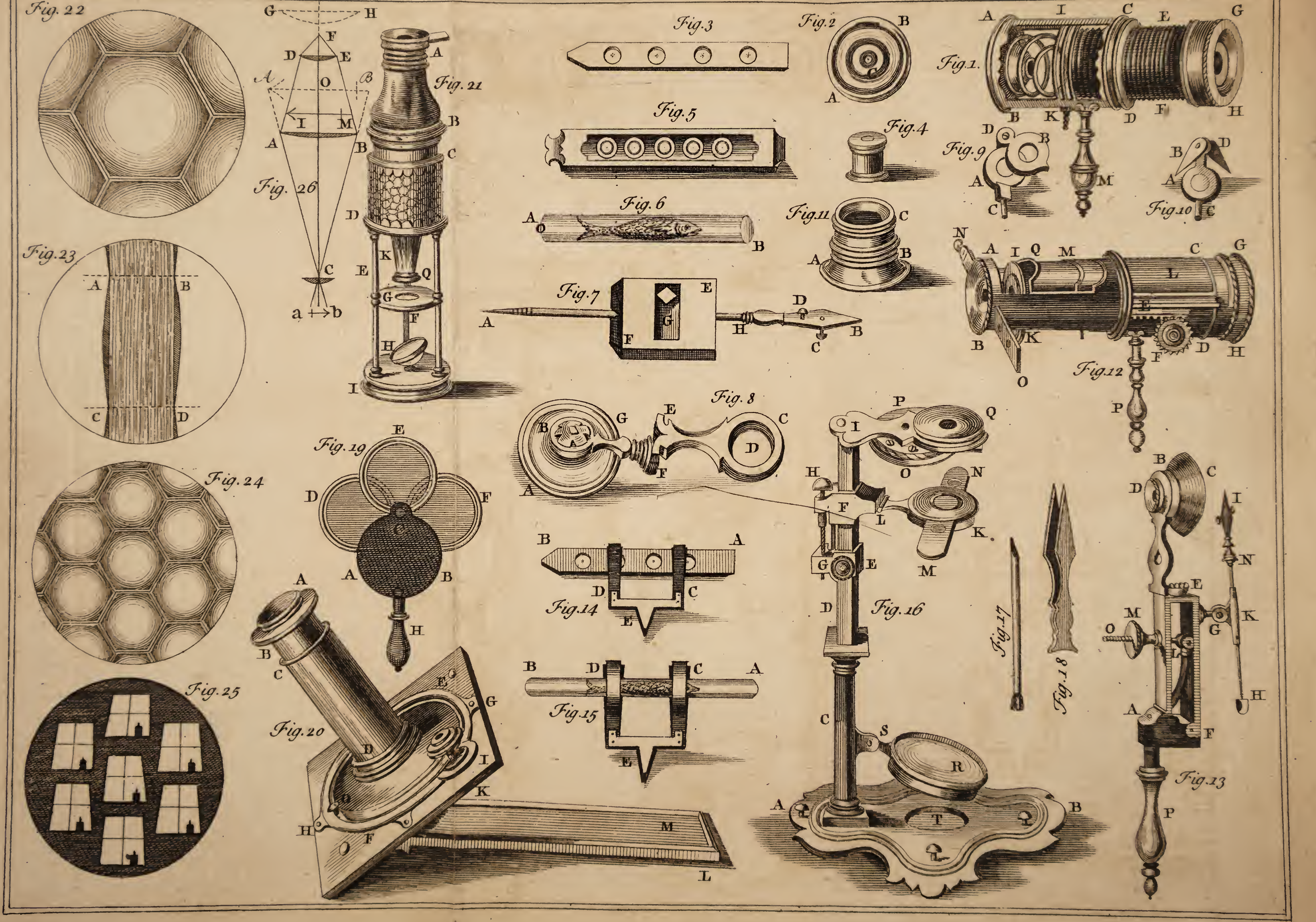
A View of the Various Sorts of MICROSCOPES, Single, Solar, and Compound; all of a Portable Form, as they are made with a compleat Apparatus by Benj.n Martin Fleetstreet.



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OPTICAL ESSAYS,

CONTAINING,

I. A *practical* DESCRIPTION of the ſeveral Sorts of *Single*, *Solar*, and *Compound* MICROSCOPES; with their *Apparatus*, and lateſt Improvements.

II. The *Nature* of VISION in INSECTS demonſtrated by *Microſcopic Obſervations*.

III. A CATALOGUE of all the *principal Microſcopic* OBJECTS.

IV. The Uſe of the *Reflecting* TELESCOPE as an univerſal PERSPECTIVE for viewing every Sort of Object in the greateſt Perfection.

V. The Manner of computing the *Magnifying* POWER in ſingle and double MICROSCOPES.

VI. A new Method of applying a MICROMETER to take the *Dimenſions* of ſmall Objects.

VII. An *Illuſtration* of the Whole in a great Variety of FIGURES on a large COPPER-PLATE.

By B. MARTIN.

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PREFACE.

THERE are ſeveral Reaſons which make it neceſſary to preſent the Public with the following Eſſays; *ſome of the Principal here follow:*

Firſt, *There has never been a general Deſcription of the practical Uſe of Microſcopes, and the ſeveral Parts of their Apparatus, publiſhed in a ſmall Size; and every Purchaſer of theſe uſeful Inſtruments can't be ſuppoſed to give themſelves the trouble of peruſing voluminous Authors upon the Subject.*

Secondly, *Moſt of the ſmall Pieces formerly publiſhed, and given with particular Microſcopes, as* Wilſon's, &c. *are now out of Print, and not to be had.*

Thirdly, *Many new Improvements have been made in the Uſe, Conſtuction, and various Application of Optical Inſtruments, which it is very proper the Public ſhould be informed of in the moſt general Manner poſſible, which is by ſhort and practical Diſſertations and Deſcriptions.*

Fourthly, *I have the common Reaſon, viz. The* Importunity of Friends, *to add to the above; for as I ſell theſe Inſtruments, nothing is more common than to be aſked for a Deſcription of them; to ſay there is none, is a Diſcouragement to Buſineſs; and conſtantly produces this Interrogation,* Why don't you write one? *To ſay*

ſay the Truth, I have given evaſive Anſwers to that Queſtion 'till I am tired; and, at length determined to do it in earneſt, and I hope to general Satisfaction, in the preſent Performance.

Fifthly, *I really found it neceſſary for my Reputation's Sake to engage in the following Work; for, as many of my Inſtruments differ in their Conſtruction from the cuſtomary Sort, I found Gentlemen apt to accuſe me of putting ſuch into their Hands as (they ſaid)* would not perform; *when the only Reaſon why they did not ſucceed was, their not being well acquainted with the Manner of uſing them rightly. Therefore it became neceſſary to give the cleareſt Ideas of the Nature and Uſe of ſuch Inſtruments, both by* verbal Deſcription, *and a Repreſentation by* Copper-plate Figures, *which is here done in great Variety.*

Sixthly, *and laſtly, to gratify my own Inclination (as an Author) in publiſhing* ſomething New, *was Part of the Inducement to this Undertaking; ſuch I hope the Public will eſteem the* NATURE *of* VISION in INSECTS, *the* CATALOGUE *of* Microſcopic OBJECTS, *the Conſtruction of an univerſal* COMPOUND MICROSCOPE, *the Manner of converting a* Reflecting TELESCOPE *into a real* PANOPTICON, *or univerſal* PERSPECTIVE; *the* new Method *of applying a* MICROMETER, *with ſome other Particulars tending to facilitate the Practice of Optical Inſtruments, and the Study of (the moſt* rational *and* divine *of all* Sciences,) *the* SCIENCE *of* OPTICS.

B. MARTIN.

I. *The* DESCRIPTION *and* USE *of* WILSON's *Pocket Single* MICROSCOPE, *and the ſeveral Parts of its* APPARATUS.

FIG. I. is the Body or Form of the Inſtrument, which conſiſts of two Parts or Tubes, *viz.*

ABDC, the external Caſe or Tube cut open on each Side, near its whole Length, for the convenient placing, and Motion of the Sliders with Objects.

EGHF the inner Tube with a long Screw on its Surface, working in the internal Screw of the outer Tube at the End CD, for the due Adjuſtment of Objects to the magnifying Glaſſes.

ABIK is that Part of the external Tube which contains a Spiral Wire bearing (by its Spring) againſt three thin Plates of Braſs, with Holes near half an Inch wide in the Middle; two of theſe are plain or even, to hold and compreſs the Sliders with Objects; and one is hollow'd thro' the Middle, in a cylindric Form, for receiving a Glaſs Tube with Objects to be view'd.

M is the Handle by which the Microſcope may be conveniently applied to the Eye, held up to the Light, *&c.*

GH is the End which holds an illuminating Glaſs, for converging the Sun Beams, or Candle Light, ſtrongly on the Objects placed near its Focus. The Aperture of this Glaſs is made greater, or leſs, by two thin concave Pieces of Braſs with Holes of different Sizes ſcrew'd ſeparately on upon the ſaid Lens. But often times Objects appear beſt in the common Light, and then this Glaſs is taken out, and laid by.

AB is the End into which the ſeveral Magnifiers are ſcrew'd to ſhew the Objects.

Fig. II. repreſents one of the magnifying Glaſſes.

AB is the circular Piece of Braſs, and C the Center, in which each Lens is placed between two thin Caps of Braſs, of a Form proper to receive and hold them without Motion. Theſe ſmall Lenſes or Magnifiers, are Six in Number, and mark'd 1, 2, 3, *&c.* on the Braſs Plates which contain them. That which has the ſhorteſt focal Diſtance, or of the leaſt Size, is the greateſt Magnifier, and is N° 1; the leaſt Power of magnifying is that of N° 6, whoſe focal Diſtance is about *One Inch*, and that of N° 1 about $\frac{1}{10}$ or $\frac{1}{15}$ Part of an Inch.

Fig. III. is the Form of the *Ivory Slider*, which has generally four ſmall round Holes deep enough to hold two Pieces of thin Talk with ſmall tranſparent Objects between them, which are kept together by a Wire Ring fitted to the Holes. This Talk (or *Muſcovy* Glaſs) is almoſt as tranſparent as common Glaſs, and admits of a very clear and perfect View of the Object. Of theſe Sliders there are Six, in the larger Apparatus; but Gentlemen may have as many as they pleaſe, paying for all above that Number. The Sliders with their Objects are put between the two thin moveable Plates of

Braſs next the Spiral Wire in the Microſcope, ſo that the Hole of the Slider may be entirely within the Holes of theſe Plates, and then by turning the Screw, they will eaſily be adjuſted to the Focus of the Lens, and the Object appear diſtinct and magnified.

N. B. It will be moſt convenient to put in the Slider with that Side downwards, or from the Eye, where the Wires are.

Fig. IV. is a ſmall Ivory cylindric Box, for containing a ſufficient Quantity of the abovemention'd Pieces of Talk, and Wires; the Talks are at one End, and the Wires at the other. So that if any chance to be loſt from the Sliders, they are hence readily ſupplied.

Fig. V. is a long braſs Caſe containing a Slip of Braſs with Holes in it juſt like the Ivory Slider, but in thoſe Holes are cemented ſmall concave Glaſſes, into which any ſmall living Object is placed, and a thin Slip of plain Glaſs being put over this braſs Slider, they are both together put into the braſs Caſe or Frame (which is open on each Side the whole Length nearly,) and being put into the Microſcope (as the Ivory Sliders are) thoſe living Objects are by this Means view'd, and all their Motions, both external and internal, are diſtinctly ſhewn; for being confin'd in theſe ſmall Cavities they are ſecure from being cruſh'd to Death, nor can they wander from the Field of View.

Fig. VI. is a thin cylindrical Glaſs Tube, AB, to receive any larger Sort of living Object, in order more perfectly to view their internal Parts and Motion of their Fluids, as the Circulation of the Blood, *&c.* in the Tails of *Fiſhes*, *Water-Newts*, *Tadpoles*, Legs of *Spiders*, and many

other

other tranſparent Animals, which may be conveniently placed in ſuch Glaſs Tubes without Hazard of their dying ſoon, becauſe, tho' they are confin'd at the open End B by a Piece of Cork, &c. there is a ſmall Hole at the other End A always open to give them Air. Nor can the Water run out at that Hole if the End B be cloſe ſtop'd, which renders it very convenient in viewing all Sorts of Animalcules and other Objects in Fluids. This is placed between the 2d and 3d moveable Plates of the Microſcope, in the Hollow of the latter. Of theſe Tubes, there are three different Sizes in a Set which go with the Apparatus: As many more may be had as the Buyer pleaſes.

Fig. VII. is a ſmall Inſtrument, conſiſting of two Parts, *viz.*

AB a ſmall Pair of Tongs or Plyers, which has a ſharp Point at the End A, and a little above it is tapped with a fine Thread or Screw. The other End B conſiſts of two ſpringy Cheeks, which open by the Preſſure of two braſs Pins C, D, for taking faſt hold of any ſmall Object.

EF is the other Part, which is a Piece of Braſs the Form and Size here ſhewn, juſt thick enough to have a Hole made thro' it to receive the round Shank or Part AH of the Plyers, which is moveable thro' it, or fix'd in any Part at Pleaſure by the Preſſure of the Spring G in the Middle Part. This Inſtrument, with that in the next Figure, is deſign'd principally for viewing opake Objects, which cannot be done in the Apparatus hitherto deſcribed.

Fig. VIII. is compounded of the following Parts, *viz.*

A G a circular Piece of Braſs with a Male Screw on the under Part by which it is ſcrewed on to the End A B of the Microſcope.

B F is an arm or Piece of Braſs, moveable about the Center of the Piece A G on its upper Part or Surface.

E C is another Part moveable about the Center in the End F of the former, by a Piece E F at right Angles to itſelf.

D is a Hole with a Screw cut in it, of the ſame Sort and Size with that in the End A B of the Microſcope; and conſequently into this Hole any of the Magnifyers A B (*Fig.* 2.) may be ſcrewed as Occaſion requires.

Therefore if the Braſs Plate E F (*Fig.* 7.) be placed between the Plates in the Microſcope at I K, with the Plyers in it; and then the Part A G (*Fig.* 8.) ſcrewed on the End A B of the Microſcope with the Magnifyer in the Hole D, it may be eaſily applied to ſhew any opake Object in the Plyers at either End A or B which is brought to the Focus of the Lens by the Screw of the Microſcope E F.

Fig. IX. Is a ſmall Part containing two Glaſſes, *viz.* A, a Piece of Braſs with a Concave Glaſs in the Center to receive any opake live Object.

B a circular Piece of Braſs with a plain Glaſs in the Center; this being moveable on the Joint D, is placed over the Object to confine it, and then the whole is ſcrewed on to the End of the Plyers (at A) by the Part C. The Animalcules in Fluids, and other tranſparent Objects may alſo be this way viewed to greater Advantage than when placed in the glazed Slider of *Fig* .5.

Fig. X. Is another Part conſiſting of a round Piece of Ivory A, one Side of which is White and the other Black, to the Intent that Black or Dark Objects being laid on the White Side, and White and Light-coloured ones laid on the Black Side, may be viewed to the greateſt Advantage. For which Purpoſe the Objects may be fixed or confined on either Side by two plain ſpringy Pieces of Steel B and D moveable about a joint; and then the Piece is ſcrewed on to the End of the Plyers A by the Shank C, (as the other was) to be adjuſted to the Lens.

Fig. XI. Is an Ivory Box or Barrel containing a Lens at A B of about an Inch focal Diſtance which being ſcrewed by the Part C in the Hole D (of *Fig.* 8.) will ſerve to magnify any larger Sort of Object in the Plyers placed in the Microſcope; or it may be held in the Hand for that Purpoſe upon Occaſion.

II. *The* DESCRIPTION *of a Single* MICROSCOPE *of a different Conſtruction with* TEETH *and* PINION, *&c.*

FIG. XII. preſents a View of the Body or general Form of this Inſtrument whoſe Parts are as follows, *viz.*

A B C D is the external Tube or Caſe.

G H I K is the internal moveable one.

Q M is Part of another Tube within the laſt, at one End of which is fixed a Plate of Braſs, hollowed in the middle for receiving the Glaſs Tube, as at Q it appears; there is alſo a moveable flat Plate between which and the fixed End I K of the ſecond Tube the Ivory Sliders are placed.

L the Part of the Microſcope which contains a ſpringy ſpiral Wire keeping the Tube Q M with its Plates always faſt againſt the fixed Part I K of the ſecond Tube.

E F is the ſmall Rack-work of Teeth and Pinion by which the Tube I G is carried gradually to or from the End A B, for adjuſting the Objects to the Focus of different Lenſes.

N O is a Braſs Slider with ſix Lenſes or Magnifying Glaſſes, any one of which may be placed before the Object inſtantly, by moving the Slider one way or the other a very little Space; you know when the Glaſs is in the Center of the Eye-hole by a ſmall Spring falling into a Notch in the Side of the Slider made againſt each Glaſs.

P is the Handle by which this Microſcope is held up to the Light for viewing Objects.

The Parts of the Apparatus in Fig. 7 and 8 may be here applied (with little Alteration) for viewing Opake Objects; and more conveniently than in the foregoing Form of the Inſtrument.

* * *

III. *A* DESCRIPTION *of the* Single OPAKE MICROSCOPE.

FIG. XIII. is the Form of the Inſtrument when fitted for Uſe.

A B E F is the Body of the Inſtrument, in which E F is a Part moveable on a Joint at F, by Means of M, O, a Nut and Screw upon a Joint at L, and a fine Steel Spring below.

H I is a Pair of Plyers moveable in K, a ſhort braſs Pipe made ſpringy at each End to graſp the Shank H N of the Plyers.

G, is the Joint on which the Part K, with it's Plyers, is moved to and from the Inſtrument. It has alſo another Motion vertically quite round, ſo that each End of the Plyers H or I may be turned upwards with the Object to be viewed by D a Lens, or ſmall Magnifyer contained in the central Part of C a concave reflecting Speculum of Silver, which throws a ſtrong Light on the Object to be viewed when brought into the Focus of the Lens.

P the Handle to hold it properly to the Light of the Candle or Sun-beams.

Fig. XIV. is a Contrivance for placing the Ivory Sliders with Objects before the Magnifyer in the Speculum.

A B is one of thoſe Sliders; C, D, two pliant double flat Steel Springs, or Cheeks, between which the Slider is placed and held firmly.

E the Shank or Part by which it is ſcrewed on to the pointed End of the Plyers at H.

Fig. XV. is the like Apparatus for holding a Tube with Animals in Water, for viewing the Circulation of the Blood, or any other Purpoſe.

A B is the Tube with the Water, Animalcule, *&c.*

C, D, the two Pair of pliant double Springs, of a form proper for holding the Tube faſt.

E the Part by which it is ſcrewed to the End of the Plyers.

It is eaſy to ſee how convenient and perfect a Form this is for a ſingle Microſcope with reſpect to magnifying every Sort of Object, great or ſmall, tranſparent or opake.

IV. *The* DESCRIPTION *of a Single* MICROSCOPE *on a* FOOT *or* STAND.

THE ſingle Microſcopes hitherto deſcribed, are all to be held in the Hand, but they have been contrived in many different Forms on a Foot or Stand, which on ſome Occaſions are very neceſſary and convenient. I have here given the Form or Structure of one which I think preferable to any I have ſeen.

FIG. XVI. is the general Form of the Inſtrument in which A B is the Baſis or Foot.

CDI is the Stem, of which the lower Part C is in the Form of a Pillar; and the upper Part D has four plain Sides.

E, F, are two ſquare Sockets of Braſs moveable up and down together upon the ſquare Part of the Stem, being connected by a common Screw; but this Motion is checked by the conſtant preſſure of a Spring.

G is a Screw by which the Part E is fixed to the Stem.

H is an adjuſting Screw, by which the Part F is gradually moved up and down; and thereby KL the Stage on which the Objects are placed, has MN the Slider, with its Objects, duly adjuſted to the Focus of the Magnifyers.

L is a Joint by which the Stage is capable of an horizontal Motion, to ſhew any Part of the Object without moving the Slider.

OP is a circular Piece of Braſs conſiſting of two Plates, between which are placed ſix ſmall Lenſes or Magnifyers in a Circle near the extreme Part, and is moveable on a Screw in its Center, which goes into IQ, a Piece of Braſs fixed very firmly on the Top of the Stem; upon this is Q a circular Piece of Braſs ſoldered on, with a Hole in the Center, under which the Circle of Glaſſes below paſſes, and, conſequently, any one of the Lenſes being brought to the Center of this Hole, will be exactly over the Center of the Hole in the Stage, and ſhew the Objects when adjuſted to the Focus of the ſaid Lens.

R is a reflecting Speculum plain or Concave to illuminate tranſparent Objects.

S a Joint fixed in the Stem C, on which it has a Motion up and down, there is a Contrivance alſo for a motion towards each Side.

T is a Hole in the Foot, with a Screw cut in it, to fix it on the Apparatus of a Solar Microſcope upon Occaſion.

Fig. XVII. is a ſmall Bruſh for cleanſing the Glaſſes, Talks, *&c.*

Fig XVIII. is a Pair of Nippers for taking up ſmall Objects, and applying them.

And theſe are all the different Forms of *Single* Microscopes that I think are neceſſary to be deſcribed. As to the *Aquatic Microſcope* all its Uſes are fully provided for in this laſt Form upon a Stand (*Fig.* 16.) Alſo the reflecting Silver Speculums are adapted to it for ſhewing Opake Objects.

Fig. XIX. is an optical Inſtrument that may be properly called a Megalascope for the Hand; becauſe it is adapted for viewing all the larger Sort of ſmall Objects, ſuch as Inſects, Flowers, Minerals, Linen, *&c.* to very great Advantage; as with three Glaſſes only it has *ſeven different magnifying Powers.*

AB is the Caſe of Braſs, Silver, *&c.*

D, E, F, three ſeveral Lenſes with different magnifying Powers, which are all contained in the ſaid Caſe, and turned out at Pleaſure.

H the Handle.

The three Glaſſes ſingly, afford three magnifying Powers; and by combining two and two, we make three more; for D with E makes one, D with F another, and E with F a third; which with the three ſingly, make ſix; and laſtly, all three combined together make another, ſo that upon the Whole, there are ſeven Powers of magnifying with three Glaſſes only.

V. *A* DESCRIPTION *of the* Solar MICROSCOPE, *with* DIRECTIONS *for its* USE.

IN ſingle Microſcopes we view the Objects largely magnified; but in a ſolar Microſcope we form the Images of thoſe Objects upon a white Screen or Wall extremely large and diſtinct in the Manner following, *viz.*

FIG. XX. repreſents the Body of the Inſtrument, except the ſingle Microſcope, which is to be ſcrewed on to it, to compleat it.

AB is the inmoſt moveable Tube, to which, upon the Screw at A, a ſingle Microſcope is to be applied.

CD is the external Tube, containing an illuminating Glaſs at the End D, and is ſcrewed into EF a circular Plate with Teeth, and moveable by I a Pinion with Teeth fixed into GH a ſquare Plate which is ſcrewed faſt on to the Window-Shutter, when the Inſtrument is uſed.

KL is a long Frame (fixed to the circular Plate E F) containing M a Looking-glaſs for reflecting the ſolar Rays to the Lens contained in the Tube at D.

O is a Worm, or endleſs Screw, which on the outſide moves a ſmall Wheel, by which the Frame of the Reflector M is moved up and down.

Theſe are the ſeveral Parts of the Inſtrument whoſe Uſe will be very eaſy if the following Directions are well obſerved.

I. The ſquare Frame GH is firſt to be ſcrewed on to the Window-ſhut, the Room being well darkened.

II. The Screen is to be placed at a proper Diſtance; the farther it is from the Window, the larger will be the Image, any Diſtance from ſix to ſixteen Feet will do.

III. The Frame K L with its Glaſs, is to be moved by the Pinion at I, one way or the other, till the Beams of the Sun's Light comes through the Hole into the Room.

IV. Then by the Worm at O the Glaſs muſt be raiſed or depreſſed till the ſolar Beam becomes horizontal or goes ſtrait acroſs the Room to the Screen, or Wall.

V. Then the Tube C D with its Lens at D is to be ſcrewed into the Hole of the Circular Plate E F; this Glaſs has a focal Diſtance of 8, 9, or 10 Inches; by which all the Beam will be converged to a Focus, and from thence, proceed diverging to the Screen, or Sheet on the Wall, and there make a large Circle of Light.

VI. The ſingle Microſcope is then to be ſcrewed on to the End A B of the inner Tube; this is moſtly of the Form of *Fig.* 12.

VII. Then the Slider N O *(Fig.* 12.) is placed with that Lens which is about the 10th of an Inch focal Diſtance, in the Center of the Hole at the End A B. This will occaſion a Circle of Light on the Screen very much larger than before.

VIII. This done, the Slider *(Fig* 3.) is placed between the Plates at I K *(Fig* 12.) and any Object placed againſt the ſmall Lens at Pleaſure.

IX. By moving the Tube A B in or out *(Fig.* 20.) you may place the Object in ſuch a Part of the condenſed Beam as ſhall ſufficiently enlighten it, and yet not ſcorch or burn it; this is generally about an Inch from the Focus.

X. It now remains only to adjuſt the Object, or bring it ſo near the manifying Lens that its Image ſhall be quite diſtinct and perfect on the Screen or Sheet, which is done by gently moving the Pinion F *(Fig.* 12.) a little one Way or the other.

XI. If the Object be large, a leſs Magnifying Lens muſt be uſed; and the ſmalleſt Objects require the deepeſt Magnifyer.

XII. The ſame Object may be ſhewn by each particular Lens applied to it, and the Degree of Magnifying is known by this Rule, *viz.*

As the Diſtance of the Object to that of its Image from the Lens, ſo are the Length and Breadth of the Object to thoſe of the Image.

N. B. In ſome Caſes, the Foot of a Single Microſcope (of *Fig.* 16.) being ſcrew'd on to the Solar Part by the Hole T, will do beſt, by Reaſon the adjuſting Screw GH is more accurate, than any Motion by Teeth and Pinion can be. Alſo *Wilſon*'s Microſcope (*Fig.* 1.) will do very well.

VI. *The* Description *and* Use *of a* Compound Microscope.

FIG. XXI. is the Form of a Compound Microſcope for the Pocket.

AQ is the Body or internal Part which is moveable up and down in CD an external Caſe of Wood, Braſs, or Silver.

E one of the three Pillars which ſupport the Inſtrument.

F a plate fixed (horizontally) to the Legs, uſually called the *Stage*.

G a hole in the central Part, in which Glaſs, and other Parts of the Apparatus are placed, with Objects to be viewed.

H an illuminating or reflecting Speculum.

I the Foot of the Inſtrument.

K is a Pipe, to which is ſcrewed

Q a Braſs Button or Caſe to hold the Magnifer.

In this Compound Microſcope there are generally three (ſometimes four) Glaſſes employ'd to produce the Effect, *viz.* (1) The magnifying Lens at Q which makes a large Image in the upper Part of the ſmall Object below. (2) A large Lens at B, called the *Body Glaſs*, which is the Cauſe of a larger Field of View. (3.) An Eye-Glaſs at A, by which we view the enlarged Image of the Object, in its Focus.

VII. *The* DESCRIPTION *of a new* UNIVERSAL MICROSCOPE.

IF the Part AB, containing the Eye-Glaſſes of the Compound Microſcope in *Fig* 21, be applied to the End GH of the ſingle Microſcope in *Fig*. 1. or rather that of *Fig*. 12. and the other End AB of the ſaid Microſcope be ſcrew'd upon the circular Part Q of the Microſcope in *Fig*. 16, then there will be conſtituted a Compound Microſcope of the moſt univerſal Kind: For you will have by this Conſtruction (1.) A *ſingle Microſcope* of the beſt Sort. (2.) A *Compound Microſcope* of a Pocket Form. (3.) This being added to the Frame or Apparatus of *Fig*. 20. makes a *Solar Microſcope* of the very beſt Sort, as before deſcribed.

It has been cuſtomary to make Compound Microſcopes in the Manner above directed; but there has always been one Deficiency in them, *viz.* a *ſmall Field of View*; this in the above Conſtruction is remedied, where the Field of View is larger and more diſtinct to the bounding Circle, than is uſual in Compound Microſcopes of the moſt bulky Sort. And in this Article conſiſt all the Perfection of the Inſtrument, and the Pleaſure of uſing it.

It may be proper to hint to ſuch as are not yet acquainted with optical Inſtruments, that the Difference between a Single and Compound Microſcope is (1.) That in a Single Microſcope you ſee the *Object itſelf*; but its *Image* only is ſeen in the Compound one. (2.) In the latter you have a much larger *Field of View*, than in the former. (3.) Compound Microſcopes are more readily applied to view *Opake Objects* than ſingle ones can be. (4.) Therefore, ſince each has its Excellencies, the prudent Purchaſer will naturally make choice of the *Univerſal Form* deſcribed in this Article, as it has all the Advantages of Microſcopic Views.

The MICROSCOPES hitherto deſcribed are all of the *dioptric Sort*, or whoſe Effects are performed by *Refraction*; there is another Sort of MICROSCOPE by REFLECTION, which has many Things to recommend it; but as that is found in the *Reflecting Teleſcope*, to the greateſt Advantage, I have given a particular Account of it in the *Deſcription of a Univerſal* REFLECTING PERSPECTIVE.

* * *

The NATURE of

VISION in INSECTS

Demonſtrated by

MICROSCOPIC OBSERVATIONS.

THE Nature and Manner of Viſion is the ſame in *Quadrupeds*, *Birds*, *Fiſhes*, *Serpents*, and many Sorts of *Reptiles*, as it is in the *Human Species*, which is now ſo very well known, that ſcarce a rational Doubt remains about it.

But the Caſe is far otherwiſe in regard to Viſion in INSECTS; this Tribe of Animals is on every Account the moſt ſingular; but in nothing, perhaps, ſo much different from all others, as in the Formation and Structure of the Eye; the moſt exquiſite Organ in the Animal Fabric. In other Creatures the Eyes are moveable, and being placed generally one on each Side the Head, two are ſufficient for all the Purpoſes of Viſion. But in Inſects the Eyes are fixed, and therefore *two* would not ſerve for a diſtinct View of Objects placed any where but juſt in the Axis of each Eye, that is, directly before them.

The *Binocular Syſtem* of Eyes, therefore, being not allowed to *Inſects*, a *Multocular One* became neceſſary; and accordingly we find all this Claſs of Animals provided with numerous fixed Eyes; and that two different Ways. For in ſome Species of Inſects we find thoſe Eyes ſingly placed, at a Diſtance from each other but ſo as to command a View of all Objects about them. This Diſpoſition of Eyes is moſt remarkable in all the *Genus* of SPIDERS.

But the *Multocular* Structure of Eyes in the generality of Inſects, is of a congeſted or compounded Nature, that is, they have to the naked Eye the Appearance of two Eyes like other Animals, but when we come to examine one of thoſe Eyes by a proper magnifying Glaſs, we preſently diſcover ſuch a Form or Figure of the external Parts as immediately induces us to conclude that this Eye is only a Collection or Congeries of an indefinite Number of very ſmall ſingle Eyes, all put together, as it were, in one common Caſe or Socket.

This Appearance of the External Part or *Cornea* is uſually called the *Lattice-Work* of a Fly's Eye, it being obſervable more or leſs in the Eyes of all ſorts of *Flies*, and winged Inſects; and is one of the moſt curious Objects of the Microſcope. This wonderful Structure of an Inſect's Eye is moſt obvious, diſtinct and perfect in that Species called the *Libella*, *Adderſpear*, or *Dragon-Fly*, of which I have given a large magnified View in the MAGAZINE of ARTS and SCIENCES, to which I refer the Reader.

Before the Invention of the Microſcope we could expect nothing relative to the Mode of Viſion in the Eyes of Inſects; but ſince that uſeful Inſtrument has been conſtantly applied to view and examine theſe Eyes, (as it were a favorite Subject,) it is ſomething wonderful that the Diſcoveries made thereby, and our Knowledge of this Matter deduced from them, ſhould continue ſo very imperfect even to this Day; eſpecially as the Eye of the *Libella* is ſo large, ſo eaſy to be diſſected, and affords the moſt obvious and direct Proof of the *Nature of* VISION *in* INSECTS.

Wotton, *Geſner*, *Penny*, *Monſel*, *Aldrovandus*, and others have wrote largely on the Subject of Inſects, but none of them ſay much of their Eyes, except admiring greatly their pearl-like Appearance. Neither *Redi*, nor *Reaumur* in his voluminous Account of Inſects gives any Light into the Doctrine of *Viſion in Inſects*. *Liſter* and *Ray*, leave this Matter as they found it. *Power*'s Microſcopical Experiments are nothing to this Purpoſe; and though he has an Anatomical Conſideration directly upon the Eye, yet he ſeems to ſpeak of the Figure and Structure of the *Cornea* of an Inſect's Eye, as if his Glaſſes had deceived him, for he aſſerts that it is full of *Perforations*, as if it were a *Tunica Uvea* pinked full of *Holes*, to uſe his own Words.

On the other Hand, his contempory Dr. *Hooke*, was ſo far from having any Notion of theſe *Foramina* or Perforations in the Eyes of Inſects, that he looked upon them, and always ſpoke of them, as Cluſters of *pear-like Protuberances*, affirming thoſe he examined in the Head of what he calls a *Drone-Fly* were really ſmall *Hemiſpheres* ſet in Rows with little Trenches or Furrows between them. This Account is quite contrary to Dr. *Power*'s.

Dr. HOOKE further obſerves, that each of theſe *Pearls*, or *Hemiſpherules*, is a *perfect Eye*, without Doubt. But his Method of accounting for Viſion in ſuch an Eye is, I believe, merely conjectural and wide of the Truth. For he ſays the *Cornea* of the Fly's Eye appeared to have as many Cavities within-ſide as there were Hemiſpherules on its outer Surface and ranged in the ſame Order; that each of theſe Cavities contained a clear Liquor; and laſtly, that at the Diſtance of a little more than the Diameter of the Hemiſphere there is a dark opake Matter or *Tunica* which he ſuppoſes to be the *Retina*; and therefore concludes that Viſion is performed in one of theſe ſmall Eyes of the Cluſter after the ſame Manner as in the Eye of a Man, *viz.* by Means of Light refracted through a convex *Cornea*, a *Watery or Glaſſy Humor*, to a *Retina* in the Fund of each little Eye.

If this be ſo (ſays the Doctor) there is in all probability a little Picture or Image of external Objects painted on the *Retina* of ſuch Hemiſpheres to which the Objects happens to be oppoſite.——From whence it is evident the Doctor had not ſeen thoſe Images by refracted Light, or confirmed this Account of Viſion by Experiments.

The celebrated Dr. SWAMMERDAM undertook the general *Anatomy of Inſects* with ſurpriſing Succeſs; and in particular he has given the Diſſection of the Eye of a Bee, in which he agrees with Dr. *Hooke*; that the external Part, or general *Cornea*, conſiſt of innumerable *little Spheres* or *Globules*; alſo, that each of theſe are of an hexagonal Form, and hollow on the Inſide; but then he denies that theſe Cavities contain any Liquor or Humour; and aſſerts, that the opake Matter (before ſuppoſed the

Retina) is really in contact, or immediately adheres to the Cavities of the general *Cornea*; and laſtly, that it is neither a *Retina*, nor *Uvea*, as there is no Perforation or Pupil in it; and conſequently that Viſion is not performed in Inſects in any Manner anologous to that in other Animals.

According to this Author, there is no Way of accounting for Viſion in Inſects at all; for, if each ſingle Globule in ſuch a compound Eye, were equally concave on the inſide, as convex on the outſide, and the inſide be lined with a dark opake Matter, then ſuch a Globule can only reflect the incident Rays, like a very minute convex Speculum, without the Poſſibility of any Image being formed by Light refracted thro' it, as is the Caſe of Viſion in all other Eyes whatſoever.

But theſe great Naturaliſts have undoubtedly fallen into a Miſtake, with reſpect to the equal Concavity of theſe Hemiſpherules; becauſe, if that was the Caſe, and the dark or opake Lining removed, the Rays of Light paſſing thro' them, would not be converged to a Focus on the Inſide, and ſo no Image could there be formed of external Objects, as is evident from the common Principles of Dioptrics: But this is not the Caſe, for in the Eye of a common Fly, it is eaſy to ſhew, that by turning the Convex part to the Light of the Window or Candle, it will be refracted through it, and thereby the Images of thoſe Objects will be formed in the proper Focuſes of thoſe *Lenticular Prominences.*

And on this Account they muſt be deemed Lenſes of ſome Sort or other, proper for Viſion by Refraction; that is, they muſt be

Convexo-Concave, *Plano-Convex*, or *Double-Convexes*; ſince no others can form Images of Objects by refracted Light. Now it can be no difficult Matter to determine which of thoſe Forms theſe multocular Lenſes have; for the Thickneſs of ſuch *Corneas* is not ſo extremely ſmall, but that in a tranverſe Fiſſure, it is very diſcernable by the Microſcope; which Appearance therefore will eaſily aſcertain the true Form and Sizes of theſe ſmall Lenſes.

Neither *Power* nor *Hooke*, has ſaid any Thing in particular about the Thickneſs of the *Cornea* of their Flies, or the Form of their fractured Edges. *Swammerdam* has given a Cut of the Thickneſs of the Cornea of a Bee's Eye, but then it does not go thro' the ſuppoſed convexo-concave Hemiſpheres, but only between them, ſo that nothing can be determined of their Figure from thence.

But from a great Number of Obſervations which I have made, I have always obſerved one uniform Appearance in the Edges of the Fragments of the *Corneas* of all Inſects I have examined, *viz.* That it was thicker in the Parts through the Middle of the pearly Protuberancies than between them, and that this Swelling-out or Increaſe of Thickneſs was equal on each Side, and exactly oppoſite, and therefore amounts to a full Proof, *That the Cornea of an Inſect's Eye, is really a Syſtem of a great Number of exceeding ſmall double and equally convex Lenſes.*

A farther Proof of this is, that the real Convexity of theſe Lenſes on each Side the *Cornea* is very conſpicuous in the Microſcope; turn which Side you will to the Glaſs, the Appearance of real and equal Convexity in the Lenſes is the ſame. Indeed it muſt be granted that a *Concave-Surface* does often appear *Convex* through a magnifying Glaſs (as they well know who uſe this Artifice for converting an *Intaglio* into a *Cameo* or Baſs Relief, for examining more exquiſitely the Goodneſs of the Work;) but there are many Circumſtances attending ſuch a Microſcopic View of theſe Lenſes, as will ſufficiently convince any one that there is no ſort of Deception attending it.

A Perſon ever ſo ſcrupulous, in admitting this Doctrine of a Lenticular *Cornea* in the Eyes of Inſects, will be inſtantly ſatisfied in taking a proper View of that in the *Libella* or Dragon-Fly——His Doubts will be all diſſipated, and he muſt aſſent to its being a moſt perfect Syſtem of double and equally convex Lenſes, all of an *hexagonal Form*; and therefore one of the moſt ſingular and ſtriking Inſtances of *Divine* GEOMETRY *and* OPTICS that the whole Creation affords.

As this wonderful Creature cuts the moſt conſpicuous Figure in all the Tribe of Inſects, and on no Account ſo much as that of its large and prominent Eyes, it ſeems very ſtrange that this Principal, this capital Subject, ſhould have been ſo little conſidered and treated of by Microſcopic Authors; eſpecially *Leeuwenhoek*, *Hooke*, and *Swammerdam*, three the greateſt Names in this Part of Natural Hiſtory. The latter, in fifty-three folio Plates, has given only one Cut of the *Libella*, and that not bigger than the Life. Dr. *Hooke*, in 33 folio Plates, has no Figure at all, either of the Fly, or any Part of it; nay, in the *Micrographia Reſtaurata*, there is no other mention made of it, but that it is the moſt remarkable of all Inſects for its fine pearled Eyes.

Leeuwenhoek (we are told in the ſame Paragraph) reckons 12544 Lenſes in each Eye of this Creature;——alſo that he obſerved in the Centre of each Lens, a minute tranſparent Spot brighter than the reſt, and ſuppoſed it to be the *Pupil* thro' which the Rays of Light are tranſmitted upon the *Retina*. This Spot (he ſays) had three Circles ſurrounding it, and ſeem'd ſeven Times leſs than the Diameter of the whole Lens. I don't wonder at this Gentleman's ſeeing (or rather aſſerting) all this, when I (who make uſe of other Eyes, and other Glaſſes) have ſo often miſcarried in endeavouring to realize many of thoſe wonderful Diſcoveries we generally take upon the Credit of his Word for undoubted Truths. Nothing like a *Pupil*, or *concentric* Circle, appears to me in any of the Lenſes of this Eye: But their true and real Appearance, Figure, Size, and Effect in regard to Viſion, are as follow:

Fig. 22. is a Repreſentation of one of thoſe *Lenſes* of an *Hexagonal Figure*, inſcribed in a Circle one Inch in Diameter; with Part of ſix others contiguous to it on every Side. The Sides by which they join, are beautifully tinged with the deepeſt Yellow or Orange coloured Light refracted thro' them; ſo that they appear like Lenſes ſet in *Gold*, variegated with three ſmall parallel Lines (in a particular Caſt of Light) as ſhewn in the Figure. But as to the Surface of the Lens, there is no other than one uniform Appearance all over, excepting what may happen to adhere to it from the Matter of the Eye behind.

The Convexity of the Lenſes is very evident by the Microſcope, and appears to be equally the ſame on both Sides. What this Degree of Convexity is, I determined pretty accurately, and have repreſented both it, and the Thickneſs of the *Cornea* in *Fig.* 23. This Thickneſs of the *Cornea* A B, C D, at the Sides of the Lenſes, I find from many different Views of it, was very near equal to half the Width A C of a Lens.

This Width or Diameter of the Lenſes I obſerved was every where the ſame to a ſurprizing Exactneſs. I meaſured the ſame by means of a Latticed-Micrometer, in which there were 50 Wires in an Inch; and between two of theſe Wires were contained $9\frac{1}{2}$ of theſe Lenſes, reckoning from Side to Side. So that 50 times $9\frac{1}{2}$ or 475 is the Number of theſe Lenſes in an Inch; or the magnified Width A C (*Fig.* 23.) is $\frac{1}{475}$ Part of an Inch. And conſequently the Thickneſs of the *Cornea* A B is about the $\frac{1}{950}$ Part of an Inch, or more exactly $\frac{1}{1000}$ Part.

Then ſince each of theſe Lenſes made a very lively and diſtinct Image by refracting the Light to a Focus, it was eaſy to determine the Radius of Convexity, as it is nearly the ſame with the focal Diſtance of a double and equally convex Lens. What this focal Diſtance is in the preſent Caſe, I determined by an adjuſting Screw fitted to the Microſcope which contained $58\frac{3}{4}$ Threads in an Inch. Then having the Lenſes perfectly in the Focus of the Glaſs, I turned the Screw backwards, till I could moſt diſtinctly ſee the Images of a diſtant Object; and having tried the Experiment with five different Lenſes, upon a Mean I found the Index of the Screw was moved thro' half a Circle, or the Screw had made half a Revolution; and conſequently the focal Diſtance of each Lens was between $\frac{1}{117}$ and $\frac{1}{118}$ of an Inch.

The focal Diſtance being thus found near eight times greater than the Thickneſs of the Lens, ſhews the Radius of the Sphere, of which theſe Lenſes are Segments, to be nearly the ſame; that is about the 120th Part of an Inch; being greater than the focal Diſtance in the proportion of 49 to 48, as we know from a Theorem in *Dioptrics*.

All that I have ſaid is upon Suppoſition that the Ratio of the Sines of Incidence and Refraction is the ſame in the Subſtance of the *Cornea* of the *Libella* as it is in Glaſs; and of this there can be but little doubt, ſince it is eaſy to obſerve all the Properties of thin Plates of Glaſs in it; for it is as tranſparent as Glaſs; and likewiſe as brittle; flying in innumerale little Fragments before the Edges of the Sciſſars which divides it.

It is amazing to obſerve how perfectly ſpherical theſe Lenſes are, and how exactly the Images of Objects are defined in their Foci. The Candle, the Flame, and the Snuff, are all diſtinct and viſible in about 40 or 50 Images together. But the Objects I made uſe of for meaſuring the focal Diſtance, was a Chimney with a Funnel upon the Top of it, belonging to a Houſe in the Street, juſt oppoſite to the Window of my Room. And ſo very truly ſpherical are theſe ſmall Lenſes, that any Part or Fragment exhibits an Image equally juſt as that of the whole Lens; all in the ſame Manner as we find in broken Lenſes of Glaſs.*

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* See *Fig.* 24, which repreſents ſeven compleate Lenſes magnified; and *Fig.* 25, which are the ſeven Images of the Window and Chimney belonging to each Lens in its reſpective Focus, juſt as large as they appeared.

Since 475 of theſe Lenſes make an Inch, there will be 2256 $\frac{1}{4}$ in every ſquare Tenth of an Inch; and if we allow the *Cornea* of the *Libella* to be equal to Six ſuch ſquare Tenths, there will be 13537$\frac{1}{2}$ of theſe Lenſes in each Eye, or 27075 in both together.

Such then is the *Theory of Viſion* in INSECTS; which we may obſerve is not very diſſimilar from that in us; we have *two Lenſes*, (or Cryſtalline Humours,) and they have Ten Thouſand; and it is juſt the ſame thing whether the Ideas of Viſion be excited in the Mind of a Man or a Fly by the coincidence of *two Images*, or that of *ever ſo many Thouſands*, upon the Optic Nerve.

In ſeveral Eyes of this Inſect which I have diſſected, it was eaſy with a good Magnifyer to ſee the *Optic* Nerve proceed from (what may be called) the BRAIN to each Eye, in a round long Body, as in the Eyes of other Animals; and when it enters the Eye it is viſibly ramified in a moſt beautiful Manner, over all the interior Part of the *Choroides*, through which it penetrates and makes the *Retina* juſt under the *Cornea*, as in other Eyes. This *Retina* I have alſo taken off, and diſplay'd it on a Glaſs with a little Water, when I could eaſily obſerve ſeveral fine hollow Veſſels ſpread through the ſame, analogous to Blood-veſſels in other Animals.

This Subject of Viſion in Inſects I have given not only as new, but as the moſt ſignal and illuſtrious Inſtance of the Uſe of the Microſcope in examining the Works, and diſcovering the Wonders of Nature in her moſt ſecret Receſſes.

An Account Of the PRINCIPAL OBJECTS Which afford the higheſt ENTERTAINMENT And INSTRUCTION By the MICROSCOPE.

THESE Objects may be divided into the following Claſſes, *viz.*

I. Such as have their whole Body, Form, and Parts magnified and exhibited in one Microſcopic View; as

The Louse.
The Flea.
The Bug.
The Mite.
The Polype.
The Eels in Paſte, Vinegar, *&c.*
The Animalcules in Fluids.
Animalculæ in Semine Maſculino.

Very ſmall FLIES and INSECTS of all Sorts.
The ſmalleſt Kinds of PLANTS, MOSSES, MOULDINESS, &c.

II. The ſmall PARTS of ANIMALS, *viz.*
The HAIR of the Head, HORSE-HAIR; MOUSE'S HAIR; *Hog*'s BRISTLES, &c.
The human CUTICLE, or *Scarf-Skin.*
The *Papillæ pyramidales* in the SKIN.
The *Fibrillæ* of MUSCLES, NERVES, &c.
The RAMIFICATION of ARTERIES and VEINS.
The LYMPHADUCTS, LACTEALS, and other fine Veſſels.
The BLOOD, SEMEN, URINE, &c.
The CIRCULATION of the BLOOD in the FINS of FISHES, the TAILS of TADPOLES, and of WATER-NEWTS, the beſt of all.
The NAILS and HOOFS cut into thin Slices,
The *Plumulæ* or PLUMAGE of *Feathers.*
The PITH of a *Feather* cut tranſverſely.
The COLOURS and TINTS of *Feathers*, *Eggs*, &c. of FOWL.
The EGGS of all Kinds of Inſects.
The *Antennæ* or FEELERS of GNATS, &c.
The EYES of all Inſects.
The beautiful HEAD of a FLESH-FLY.
The *Annuli*, or RINGS, on the Bodies of INSECTS.
The WINGS of *Gnats*, *Flies*, &c.
The WINGS of *Scarabs*, or *Beetles.*
The WINGS of BUTTERFLIES, MOTHS, &c.
The STING of a *Bee*, *Waſp*, *Hornet*, &c.
The EYES of SPIDERS.
The *Exuviæ*, or *Caſt-Skins* of SPIDERS.
The *Apparatus* in the Mouths of SPIDERS.
The ſpiral *Proboſcis* in BUTTERFLIES, &c.

The TEETH in the Mouth of a SNAIL.
The EYES on the HORNS of SNAILS.
Young SPIDERS, CATTERPILLERS, *&c.* juſt hatched.
The WEB of *Spiders*, *Caterpillars*, *Silk-Worms*, *&c.*
The *Chryſalides*, or *Caſes* of Inſects.
The *Thecæ* of MOTHS, *Cados-Worms*, *&c.*
The SCALES of FISHES, SERPENTS, *&c.*
The SCALES of EELS, in particular.
The *tranſparent* FINS of FISHES and EELS.
The *Spiculæ* or PRICLES of *Seal-Skins.*
The *Ovarium* or SPERM of FISHES.
The minute Sorts of SHELL-FISH.
The *fimbriated* Parts of CRABS, LOBSTERS, *&c.*
The EXCREMENTS of SCOLLOPS, *&c.*

III. The third Claſs of Microſcopic Objects are of the Vegetable Kind; the Parts of a Plant when examined by this Inſtrument, diſcover the moſt extenſive Scenes of creating Power, Wiſdom, and Deſign, as will be eaſily evinced by applying the Microſcope to the following Subjects, *viz.*

The *Plantule* in the *Fruit*, or *Kernel.*
The CORPUSCLES of the two *Lobes* macerated.
The ORIFICES of AIR-VESSELS in the *Roots*, and *Branches.*
The ORIFICES of the SAP-VESSELS in ditto.
The *Cortex* or BARK of Trees in General.
The *Veſicular Subſtance* of CORK in particular.
The *Lignous Fibres* in the internal *Bark.*
The *Spiral* FIBRES of the Veſſels in a *Vine-Leaf.*
The *Web-like Warp and Woof* in rotten Wood.

The PITH of ELDER, and other like Plants.
The *Tranſverſe Section* of KEX, BRAMBLE, *&c.*
The *Tranſverſe Section* of the Root of FERN.
The *Involucra* or *Coverings* of GEMS or BUDS of Trees.
The *Aromatic* BALLS on LEAVES of SAGE, THYME, MINT, *&c.*
The *Catenary Pearls* on *Sowthiſtle* Leave, *&c.*
The PELLICLE or thin Skin of *macerated* LEAVES.
The *Papillæ* and PORES in the Pellicle of *Houſeleek.*
The PARTICLES of the *Parenchyma* of *macerated* LEAVES.
The RAMIFICATION of VESSELS in ditto.
The DUPLICATURE of VESSELS in ditto.
The *tranſparent* BLADES of GRASS, CORN, *&c.*
The STINGS of NETTLES, and their JUICE or LIQUOR.
The *Uncated* TENTERS, or HOOKS of *Clivers, &c.*
The *Stamina* on the young Shoots of *Filbert-Trees.*
The *Lanugo* or DOWN on the *Leaves* of Plants.
The *ſmall* FLOWERS of PLANTS in general.
The COLOURS of the *Petala* or LEAVES.
The *Farina* or Duſt on the *Stamina.*
The STYLE, *Matrix, &c.* in the *Attire* of the FLOWERS.
The *ſucculent pulpy Part* of the FRUIT.
The ſmall SEEDS of PLANTS in general.
The SEEDS of *Fern, Harts-Tongue, &c.* in particular.
The SEEDS on the Stems of MUSHROOMS.
The whole of SEA-PLANTS of every Kind.
The Variety in the Surface of CORALLINES.

The particular Texture of SPONGE.
The minuteſt *Shells* of every Sort.

IV. The fourth Claſs of Objects proper for the Microſcope are of a Miſcellaneous Nature, the Principal of which here follow.

The EDGE of a RASOR, *Pen-Knife*, *&c.*
The POINT of a *Needle*, *Pin*, *&c.*
The *poliſhed* SURFACE of *Metals*.
The PRINT, or *Writing*, on *Paper*.
The SUBSTANCE of PAPER itſelf.
The CONTEXTURE of *Linen*, *Cloth*, *&c.*
The fineſt Sorts of SAND.
The PARTICLES of different Kinds of EARTH.
The various coloured Particles of *Mundick*.
The SURFACE and SUBSTANCE of *Ores* and *Metals*.
The *Efflorescencies* of *ſparry Exudations*.
The SALTS of *Sea-Water* evaporated.
The SALTS of *Vegetable Lixiviums*.
The SALTS of *Animal Subſtances*.
The SALTS or CRYSTALS of all *Metals*.
The *artificial* CRYSTALLIZATIONS of *Salts*.
The PARTS of the ſmalleſt *Fleaks* of *Snow*.
The *hexagonal* CUPS of *white Froſt*.
The *froſty* VEGETATION on *Glaſs-Windows*.
The EFFERVESCENCE betwixt *Acids* and *Alcali's*.
The *ignited* PARTICLES in *ſtriking Fire*.
The *inteſtine* MOTION in *Spirituous-Fluids*.
The ASHES of burnt *Paper*, *Linen*, *&c.*
The TEETH of fine *Files*, *Raſps*, *&c.*
The *Threads* on the fineſt SCREWS.
The ſmalleſt *Microſcopic* GLASSES themſelves.

The DESCRIPTION of an UNIVERSAL PERSPECTIVE By REFLECTION,

Exhibiting a VIEW of all KINDS of OBJECTS, GREAT or SMALL, REMOTE or NEAR at HAND.

THE Body of this UNIVERSAL PERSPECTIVE by Reflection is in the Form of that New Reflecting Teleſcope conſiſting of a double Tube, or one within the other, whoſe Nature and Effects I have particularly deſcribed in my *Philoſophia Britannica (Edit. 2d.)* ſome Years ago; where, at the ſame Time, I hinted how very general and extenſive the Uſe of this Inſtrument was in its own Nature; and of which I ſhall now give a more particular Account and Deſcription under the following Heads.

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I. *The* USE *of this Inſtrument as a* REFLECTING TELESCOPE.

THERE can be but little neceſſary to be ſaid in this reſpect, to any one acquainted with a *Reflecting Teleſcope* in general, and eſpecially to a

Perſon who has ſeen or uſed one of the Form under Conſideration; but ſuch as have not, may obſerve the following Directions, *viz.* (1.) To take off the Piece containing the dark Glaſs at the End of the Eye-Piece, in all Caſes, except when the Sun itſelf is to be viewed *through the Tube*; and then it muſt be kept on, to defend the Eye againſt the Force of the condenſed Rays. (2.) Having directed it to any diſtant Object, you adjuſt it to a proper Focus by turning the Pinion on the Side of the outer Tube which will move the inner one *out*, and *in*, till the two Metals have their proper Diſtance to ſhew the Object very diſtinctly. (3.) For all the heavenly Bodies, and thoſe at very great Diſtances on the Earth or Sea, this focal Diſtance is the ſame, and is marked by a Circle drawn upon the inmoſt Tube. (4.) If the Teleſcope be large, the Slider carrying the little Metal, is moveable by the Hand upon the long Wire on the Side of the Tube, till you ſee the Object; and then it is fixed on the ſaid Wire by a Screw; after which you adjuſt it to a proper Focus for ſhewing the Object perfectly, by turning a Knob at the End of the Wire (next the Eye) which will give Motion to the Wire and the little Metal upon it, as in Reflecting Teleſcopes of the common Forms. (5.) The Apertures in theſe large Teleſcopes admit of too much Light for ſhewing the Planet *Venus* diſtinctly, and therefore there is, generally, a double End-Piece, *viz.* a ſmall Piece ſcrewed into a large one which cloſes the whole Tube; this ſmaller Piece is then to be taken off only, by which Means the Planet will appear like a Lunar Creſcent, or Moon of four or five Days old. (6.) This ſmall Aperture is ſometimes moſt advantagiouſly uſed for viewing the *Maculæ* and *Feculæ* or dark and light Spots on the Sun's Diſk. But for our own *Moon*, as alſo for the other *Planets*, and their *Moons*, there cannot be too much Light, and therefore in viewing them, the whole End is taken off; as likewiſe for all *terreſtrial Objects*.

II. *The Uſe of this* PERSPECTIVE *as an* ENGYSCOPE.

BY the Word *Engyſcope* is meant a *View of Objects* that are *near us*; ſuch, we are here to underſtand, as are not farther off from the End of the Teleſcope than 20 Feet; and to adjuſt the Inſtrument to a proper Focus, for ſuch near Objects, there is a Circle drawn on a proper Part of the inner Tube, to which it is to be placed by the Screw on the Side for viewing any Object at about 20 Feet diſtant from you. If it be nearer, the Tube (by turning the Screw) muſt be moved further out, till you come to a Focus, or a clear and diſtinct View of the Object, which may eaſily be obtained for any Object whoſe Diſtance is not leſs than four times the focal Diſtance of the large Metal. Thus in the *Portable* or *Pocket Reflector*, you view any Object whoſe Diſtance is not leſs than two Feet.

III. *The Uſe of this* PERSPECTIVE *as a* MEGALASCOPE.

BY a MEGALASCOPE is underſtood an Inſtrument which gives a *magnified View* of all the larger Sort of *ſmall Objects*, and is ſometimes called a *Foſſil-Microſcope*, *Cloth-Microſcope*, *&c.* but this Perſpective is of the moſt general Nature for ſhewing any thing of that Kind inſtantly, and in the moſt perfect Manner; by only placing the Object in a proper Light, and at the Diſtance of two, three, or four Feet according to the Length of your Inſtrument: For then the Objects are ſo much magnified, and their Parts ſo ſeparate and diſtinct, that we ſcarcely know them in this new Point of View, or can reconcile them to the Ideas they impreſs on the Mind by the natural Appearance.

* * *

IV. *The Uſe of this* PERSPECTIVE *as a* CATOPTRIC MICROSCOPE.

THE Nature of this Inſtrument is ſuch as fits it for a *Catoptric Microſcope* in the moſt compleat Manner poſſible; by ſuch a MICROSCOPE is meant One, wherein we view the Image of a ſmall Object, form'd by *reflected Light* from the ſmall Metalic Speculum; now it is well known, that an Image by reflected Light is more ſimple and perfect than one by refracted Light; and has this Peculiarity, that it is entirely colourleſs.

On all which Accounts it is obvious, that a *Microſcope by Reflection* is the moſt elegible to the judicious Enquirer into Nature, as being the beſt Effect that can be produced by the joint Powers of Nature and Art. And in order to render the Application of the ſmalleſt Objects facile, there is a convenient Apparatus for the Purpoſe; and the Power of magnifying is increaſed or diminiſhed by moving the ſmall Metal farther from, or nearer to the large One, by the Pinion or Screw on the Side; but this is more effectually done by an Eye-Piece of different magnifying Powers, hereafter deſcribed.

* * *

V. *The Uſe of the* PERSPECTIVE *as a* HELIOSCOPE.

BY the Word HELIOSCOPE is meant any inſtrument by which the *Sun may be viewed* without Offence to the Eye; the Method of doing which is five Fold, *two* by viewing the real Orb or Diſk of the Sun; and *three* by making the Image thereof very large, and eaſy to the Eye.

The *firſt*, is the common Way of viewing the Sun by means of the dark Glaſs at the End of the Eye-Piece next the Eye; but this gives a falſe Idea of the Colour of the Sun which we think from thence to be red, and ſo have introduced the abſurd Cuſtom of repreſenting it by a Copper, or laquered Braſs Ball in Orreries, *&c.*

The *ſecond Method* is cauſing the Sun's Rays (after Reflection from the ſmall Speculum) to be four Times reflected from ſo many plain Glaſſes, by which means ſo much Light is loſt, that the Reſidue is quite ſufficient to ſhew the Surface of the Sun with Eaſe and Pleaſure to the Eye, and preſents the true Idea of a globular Orb of white concentrated Fire. But this Apparatus adds conſiderably to the Expence of the Inſtrument.

The *Third Way* of ſhewing the Sun is by Reflection only, and therefore the moſt perfect of all others of Courſe, for the Image of the Sun formed by the large Speculum juſt before the ſmall one, is by that again reflected through the Hole of the large one, and conſiderably magnified on a Screen at a Diſtance from the Eye-End of the Inſtrument, having firſt taken off the Eye-Piece, with its two Glaſſes, and laid it aſide. For this Purpoſe it will be neceſſary only to cut a round Hole in a Sheet of Paſtboard to place it on the Object End of the Perſpective, in order to intercept the Light from the Screen; and by turning the Pinion (or Screw) on the Side, you immediately make the Solar Image very perfect on the Screen at any Diſtance. And the White as well as the Black Spots on the Sun will this Way appear beſt defined, eſpecially if the Perſpective be of the largeſt Sort.

The *fourth Method* is by magnifying the ſecond Image of the Sun a third time by the Glaſſes in the Eye-Piece, which muſt now be put on again for that purpoſe; this third Image will be very large but not quite ſo diſtinct, as before. However it is an excellent Method for exhibiting the Spots in the Sun for general Obſervation.

The Focus is here alſo (as in all Caſes) produced by turning the Pinion (or Screw) on the Side.

But the *fifth Method* of magnifying the ſecond Image by a ſmall Speculum of Metal (provided for this Purpoſe) is preferable to the foregoing; for now the third Image is alſo made by Reflection, conſequently without Colours, and as large as you pleaſe to have it, from ten to twenty Inches diameter. This Method requires a Screen or ſheet of Paſteboard fixed on the Object End of the Perſpective, or ſtanding on the Table by it, to receive the ſaid Image of the Sun.

* * *

VI. *The* USE *of the* PERSPECTIVE *as a* SOLAR MICROSCOPE *by* Refraction.

TO this End the common Eye-Piece is taken off, and a *Wilſon's Microſcope* (of a proper Conſtruction to anſwer this Purpoſe) is ſcrew'd into its Place, then a Screen being placed at the Diſtance of two or three Feet (and ſhaded by the Paſteboard on the other End of the Tube) you put the Objects (intended to be magnified) in the Microſcope, and Screw on ſuch a Magnifier as is ſuitable to their Size; thoſe Objects that are largeſt, requiring the largeſt Lens, or leaſt Magnifier, *& vice verſâ.*

When this is done, you adjuſt the Object to a due Focus by turning the Screw of the Microſcope 'till the Image becomes very plain and diſtinct on the Screen, as in the uſual Manner.

Then in order to illuminate it thoroughly, you turn the Pinion (or Screw) by the Side of the Perſpective, 'till the third Image of the Sun be formed on the Screen, which you will know by the *Maculæ*, (or by the Limb of the Sun) appearing moſt diſtinct, in the Manner as before directed.

Then it is evident, you have the Image of the Object magnified on the Image or Face of the Sun; and how beautiful a Sight this is, they beſt know who have ſeen it in the greateſt Perfection. Nor can this curious *Phænomenon* be produced in any other Inſtrument or Way that I know of.

VII. *The* USE *of the* PERSPECTIVE *as a* SOLAR MICROSCOPE *by* Reflection.

THE foregoing Way by Refraction gives not the magnified Image ſo perfect as it may be made by Reflection of Light from Metals only.

For this Purpoſe, the Apparatus forming the Solar Image (in the *fifth Method* of the 5th Article) is to be applied, and the ſaid Image made, as there directed, on the Screen, placed on the End of the Tube, or ſtanding on a Foot cloſe by it.

This being done, the Braſs Piece, with the Plyers, holding the ſmall tranſparent Object, is ſcrew'd on, ſo as to have the Object eaſily brought to its proper focal Diſtance from the ſmall Speculum, and then its Image will be diſtinctly formed, and largely magnified on the

Face or Image of the Sun, but without Colours or Diſtortion of the fineſt Parts. This Method of a *Solar Microſcope* is, of all others, the moſt pleaſing and perfect; and not in the leaſt difficult to an ingenious Hand.

* * *

VIII. *To* encreaſe *or* diminiſh *the* Magnifying POWER *of the* PERSPECTIVE *at Pleaſure.*

TO effect this, we need only conſider, that if the Diſtance between the two Lenſes in the Eye-Piece be varied, their joint Power of magnifying will be varied likewiſe, and conſequently that of the Perſpective will, by this means, become variable. Thus by the Theory it will appear, that if the focal Diſtances of the two Lenſes be 5 and $1\frac{1}{4}$ Inches, and the Eye-Piece ſo conſtructed, that they may be placed at given Diſtances from each other, the End is anſwered.

For Example, Let their Diſtance be $1\frac{1}{2}$, then they will anſwer to a Lens of $1\frac{3}{10}$ nearly; again, if we make their Diſtance four Inches, they will magnify as much as a Lens of $2\frac{4}{5}$; and in theſe two Caſes, the magnified Power of the Perſpective will be as $2\frac{4}{5}$ to $1\frac{3}{10}$, or as 28 to 13. And therefore a Foot Perſpective with ſuch an Eye-Piece, may magnify from 26 to 56 times in the linear Dimenſions. And in larger ones the Power of magnifying may be ſtill more different and variable.

IX. *To conſtruct this* Perspective *with* Metals *or* Speculums *only, ſo as to render it purely a* Reflector, *and truly* Achromatic.

AS the Body of this Perſpective contains two Metals, ſo the Eye-Piece may be conſtructed with two *Metaline Speculums*, inſtead of *two Lenſes*, always hitherto uſed. The Reaſon of this is evident from the Theory, and it is now ſome Years ſince I firſt made *Reflecting Teleſcopes* with Speculums only, and effected Viſion by Reflection entirely; and conſequently free from all Poſſibility of Colours, which we have elſewhere ſhewn, can never be perfectly prevented in any Conſtruction with Glaſſes. Therefore it is by *reflex Viſion* only, that an optical Inſtrument truly *Achromatic* or *Colourleſs*, can poſſibly be conſtructed.

THE METHOD of COMPUTING THE MAGNIFYING POWER OF SINGLE and DOUBLE MICROSCOPES.

THE *Magnifying Power* in all optical Inſtruments depends upon this one Principle, *That every Object is apparently greater or leſs in Proportion*, *as it is nearer to*, *or farther from the Eye*; becauſe the nearer it is, the larger is the *viſual Angle* under which it appears, *& vice verſâ.*

But the Eye is ſo form'd as to admit of diſtinct Viſion by ſuch Rays only as are nearly parallel; and therefore every Object muſt be removed to ſuch a Diſtance from the Eye that the Rays of Light iſſuing from every Point thereof, may fall upon the Eye with ſmall Divergency, or nearly parallel, which Diſtance is in different Eyes from *Six to Eight Inches*, as any one may find by Trial.

Now, ſince a convex Glaſs convenes parallel Rays to a Point or *Focus*; therefore, on the contrary, if an Object be placed in the Focus of ſuch a Lens, the Rays proceeding from each Point will be refracted parallel to the Eye, and thereby produce *diſtinct Viſion of that Object in its Focus.*

Hence then it follows, that if *a b (Fig.* 26.) be a very ſmall Object in the Focus of the Glaſs *c*, whoſe focal Diſtance is one Inch, the Eye applied to the Lens C will have diſtinct Viſion thereof; and this being at a Diſtance 6, 7, or 8 Times nearer than the Eye alone could clearly ſee it, it muſt appear ſo many times larger than to the naked Eye; and therefore we properly ſay, it is magnified to ſuch Eyes, 6, 7, or 8 Times in Length and Breadth.

But all SURFACES are magnified in Proportion to the *Squares of their Lengths or Sides*; therefore the Surfaces of Objects are magnified 36, 49, or 84 Times by a Lens of *one Inch focal Diſtance.*

Alſo the Bulk, or Magnitude of the whole Body, will be magnified in *Proportion to the Cubes of the Sides or Length*, and therefore all SOLID BODIES will, by ſuch a Lens, be magnified 216, 343, or 512 Times, to ſuch Eyes reſpectively.

If the Lens C were but of $\frac{1}{2}$ an Inch focal Diſtance, the Lengths of Objects would be magnified *twice* as much; the Surfaces *four* Times, and the Magnitude or Bulk, *eight* Times as much as before.

If the *focal Diſtance* of the Lens C be $\frac{1}{4}$ of an Inch, then the Lengths are magnified four

Times as much, *viz.* 24, 28, or 32 Times; the Surfaces 16 Times as much, or 576 Times more than to the naked Eye at 6 Inches Diſtance; and ſolid Bodies are magnified 64 Times more than by the Lens of a whole Inch focal Diſtance.

Once more; ſuppoſe the Lens ſo ſmall that its focal Diſtance is but $\frac{1}{10}$ of an Inch, then the *Length* of an Object is magnified 60, 70, or 80 Times; the *Surface* 3600, 4900, or 6400 Times, and the Solidity or whole Bulk 216000, 343000, or 512000 Times, or ſo much larger do the Bodies of *Mites*, or their *Eggs*, appear than to the naked Eye at 6, 7, or 8 Inches Diſtance.

After the ſame Manner you may compute the magnifying Power of Lenſes of $\frac{1}{20}$, $\frac{1}{30}$, $\frac{1}{40}$, and even $\frac{1}{50}$ Part of *an Inch focal Diſtance*, for ſuch we have made when required; but they are with Difficulty uſed. By a Lens $\frac{1}{50}$ of an Inch, the Length is magnified 300 Times; the Surface 90000 Times; and the Solidity 27000000 Times.

But theſe enormous Powers of magnifying are much better effected in COMPOUND MICROSCOPES, and be that in what Degree you pleaſe, it is thus eaſily eſtimated. Let C (*Fig.* 26.) be the *Object Lens* in the Cell Q of the Compound Microſcope, (*Fig.* 21.) if then a ſmall Object, *a b*, be placed on the Stage (at G) a little more than the focal Diſtance, there will be formed by the ſaid Lens C a large Image A B, in the upper Part of the Microſcope, and this Image is view'd through the Glaſs G H in its Focus below at O.

Now it is eaſy to underſtand that the Image *A B* is as much larger than the object *a b* as the Diſtance C A exceeds the Diſtance C *a*, from the Lens. Suppoſe the Image A B ſix Times larger than the Object *a b*; then if it be viewed by a Lens G H of one Inch focal Diſtance, the Image *A B* will appear magnified ſix Times at leaſt, and therefore the Object *a b*, will be magnified ſix Times ſix, or 36 Times *in Length*; and 36 Times 36, or 1296 Times in Surface; and 36 Times 1296, or 46656 Times in the *Bulk* or *Solidity*. And yet with theſe great Powers of magnifying, the Lens C may not be of leſs than $\frac{1}{2}$ *an Inch focal Diſtance*, in the leaſt Sort of *Compound Pocket Microſcopes*.

But with a ſingle Eye-Glaſs G H, we have too ſmall a *Field of View*, therefore we uſe two, *viz.* A B, and D E, the firſt contracts the Image *A B*, into another, I M, which is leſs, and this is viewed by the Eye-Glaſs D E. Now both theſe Glaſſes may have a magnifying Power equal to that of a given ſingle Glaſs G H by this Rule; *Let their Diſtance be equal to the Difference of their focal Lengths, and their magnifying Power will be equal to that of a Lens whoſe focal Diſtance is half that of the greater* A B.

For Example, Suppoſe the focal Length of A B to be 2 $\frac{1}{2}$ Inches, and that of D E one Inch; then if their Diſtance be 1 $\frac{1}{2}$, their joint magnifying Power will be equal to that of a ſingle Lens G H, whoſe focal Diſtance is 1 $\frac{1}{4}$, equal half that of A B. By the two Eye-Glaſſes the Rays are converged to the Eye at the compound Focus F, much leſs affected by the Errors ariſing from the Aberration of Rays, both from *their different Refrangibility*, and *the Figure of the Glaſſes.*

OF THE

NATURE and USE

OF THE

MICROMETER,

In Meaſuring

Small OBJECTS,

Exemplified in one of a

NEW CONSTRUCTION.

MANY and expenſive have been the Contrivances for meaſuring ſmall Objects, in all their Dimenſions, by that Inſtrument called, a MICROMETER; I ſhall refer the Reader to the ſeveral Writers on Optics for an Account of them, and ſhall here only propoſe one other Method, which will come eaſy, and be very ready in Practice; the Conſtruction of which is a ſufficient Explanation of its Reaſon and Uſe.

This NEW MICROMETRR is nothing more than a Stage (on which the Objects are placed) moveable by a *fine* Screw which has a *Hand* or ſmall *Index* paſſing over the Diviſions of a graduated Circle. A fine threaded Screw is the eſſential Part in all Micrometers, of the beſt or moſt perfect Kind. I formerly placed this Screw in the Focus of the Eye-Glaſs D E, (*Fig.* 26.) juſt where the Image I M is formed; but found this Method of applying it gave ſome Trouble in underſtanding and computing the Dimenſions taken by it; and therefore I have here applied it to the Stage, or rather to the Object itſelf; which being attended with no Difficulty, will, I preſume, render the Uſe of it more general and pleaſurable.

The upper Part of the Microſcope which contains the Glaſs D E has a very fine Wire in its Focus, and to it any Part of the Image I M may be applied; or that Wire may be applied to any Part of the Image, by a proper Conſtruction of the upper Part of the Microſcope for that Purpoſe. The Object being then placed in a proper Manner on the Stage, the Screw is to be turned, 'till the Image of the Object has paſſed its whole Length or Breadth under the Wire, and then the Quantity of its Dimenſion will be known. Thus for Example:

The Number of Threads on the Screw in *one Inch* is 50, and the Number of Diviſions on the circular Plate is 20. Therefore one Thread, or one Turn of the Screw, meaſures $\frac{1}{50}$ Part of an Inch; and one Diviſion of the Plate is $\frac{1}{20}$ of $\frac{1}{50}$, that is $\frac{1}{1000}$ Part of an Inch. So that ſuch a Micrometer will very exactly meaſure any ſmall Object, or its ſmaller Parts, *to the thouſandth Part of an Inch.*

Suppoſe the Subject were a MITE, and it were required to meaſure the Length thereof; then I place it in a Slider, and that Slider on a Stage in ſuch a Manner that the Mite may move length-wiſe in the Direction of a Screw, then I move or ſet the Wire at right Angles thereto, and ſo as to touch the Image of the *Mite* at one End, very exactly. This done, I turn the Wire 'till the Image has paſſed its whole Length under the Wire; and having counted the Turns, I find them 4, and 14 Diviſion of another; the 4 Turns are $\frac{4}{50}$ or $\frac{80}{1000}$, and the 14 Diviſions are $\frac{14}{1000}$; ſo that the whole Length of the Mite is $\frac{94}{1000}$ Part of an Inch, which is almoſt $\frac{1}{10}$ Part of an Inch.

Again, for a ſecond Example: Suppoſe you meaſure the Length of the EGG *of a* MITE, and find *one* Turn of the Screw, and *three* Diviſions on the Plate, carry it compleatly under the Wire; then one Revolution of the Screw is $\frac{1}{50}$ or $\frac{20}{1000}$, and three Diviſions are $\frac{3}{1000}$, ſo the whole Length of the EGG is equal to $\frac{23}{1000}$ of an Inch; that is, almoſt $\frac{1}{44}$ of an Inch; or 44 ſuch Eggs of a Mite will, if laid contiguouſly in a right line, be nearly equal to one Inch in Length.

I muſt here add, that the Micrometer is eaſily applied to the *univerſal* PERSPECTIVE before deſcribed, when uſed as a *ſolar* MICROSCOPE; for let a fine ſtrait Line be drawn on the Screen, and the End or Side of the Image be placed to touch it, then by turning the Srew, it will thereby be meaſured in *thouſandths* Parts of an Inch.

How great the Pleaſure ariſing to the curious Naturaliſts muſt be in the Uſe of the MICROMETER,

METER, meaſuring the ſmalleſt Objects, may be better conceived than expreſſed; when by this Means he acquires an Idea of the wonderful Diſproportion there is between the Magnitudes or Dimenſions of the ſmalleſt and largeſt Objects of the ſame Species; as between the ſmalleſt of the *finny Fry* and the largeſt *Whale*; an *Anguicula* in Vinegar and a Rattle Snake 30 or 40 Feet long. And that the Reader may have a clear Perception of ſuch a ſurpriſing Contraſt in the Works of Nature, I ſhall here give him a Calculation of the comparative Magnitude of the *Egg* of a *Mite* and that of an *Oſtrich.*

Suppoſe the length of an Oſtrich's Egg be 5 *Inches* (and ſome are larger); alſo let the Length of the Egg of a Mite be $\frac{1}{50}$ of an Inch, and ſome are leſs than that; then the Lengths of theſe two Eggs will be to each other as 5 to $\frac{1}{50}$ or 250 to 1; then as they are ſimilar Bodies, their Magnitudes will be as the *Cubes* of theſe Numbers, *viz.* as 15655000 to 1; that is in Words, *One Egg of an Oſtrich is equal to* 15 *Million* 655 *Thouſand Eggs of a Mite.* And there is great Reaſon to believe, that there are Eggs of other Animalculæ in a ſtill greater Degree leſs than thoſe of a Mite. Indeed the greateſt ſtretch of the human Mind is infinitely inſufficient to explore the amazing and inconceivable Gradations of Miniature in every Part of Nature, even at their very Commencement, and nothing but the all-piercing Eye of boundleſs Intelligence can ſee through a Series of ſuch infinitely decreaſing Progreſſions.

FINIS.

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